DNA 6168F

DNAF-1

An Analytical Fallout Prediction Model and Code

Atmospheric Science Associates
P.O. Box 307
363 Great Road
Bedford, Massachusetts 01730

31 October 1981

Final Report for Period 12 March 1980—31 October 1981

CONTRACT No. DNA 001-80-C-0197

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

THIS WORK WAS SPONSORED BY THE DEFENSE NUCLEAR AGENCY
UNDER RDT&E RMSS CODE B325080464 V99QAXNA01113 H2590D.

Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, DC 20305

TABLE 3

COMPARISON OF OBSERVED AND PREDICTED FALLOUT PATTERN STATISTICS

Observed/DNAF-1/DELFIC*/WSEG-10+

Test Shot	FM DNAF-1 DELFIC WSEG-10	Contour (Roentgen hr^{-1})	Area (km^2)	Hotline Length (km)	Azimuth (deg.)
Johnie Boy	0.245	1000	0.278/0.038/0.029/----	1.38/0.38/0.032/----	359/351/ 0/---
	0.182	100	0.539/1.00 /0.77 /1.17	2.73/2.18/2.58 /3.7	345/351/344/344
	0.187	50	1.27 /1.90 /1.79 /4.57	4.10/3.21/4.13 /8.9	343/351/343/344
			74(68)/58(42)/159(188)**	38(21)/28(3)/84(76)	
Jangle-S	0.70	500	0.117/0.390/0.144/----	0.69/1.64/1.00 /----	342/ 15/353/---
	0.483	300	0.386/0.821/0.316/----	1.50/2.49/1.23 /----	346/ 15/354/---
	0.080	100	1.44 /2.64 /2.24 /0.55	3.74/4.97/5.87 /2.8	1/ 15/355/ 10
		35	3.11 /6.99 /5.08 /5.45	5.06/9.07/7.68/10.2	6/ 15/355/ 10
			138(106)/40(46)/84(79)	79(59)/43(42)/82(76)	
Small Boy ‡	0.582	1000	0.216/0.302/0.047	1.00/0.92/0.25	71/ 64/ 66
	0.308	500	0.528/0.703/0.135	1.62/1.49/0.56	73/ 64/ 80
	-----	200	0.942/1.75 /0.564	2.22/2.62/1.69	72/ 64/ 73
		100	3.75 /3.35 /1.10	5.66/3.90/3.72	72/ 64/ 74
		50	9.03 /6.45 /4.38	8.10/5.69/6.47	75/ 64/ 72
			40(40)/63(59)	19(22)/44(36)	
Koon	0.515	500	32.0 /55.9 /26.0 /5.7	10.2/14.8/12.5 /5.0	18/11.3/ 0/ 9
	0.287	250	122 /13.8 /87 /70	17.3/22.7/24.2 /18.4	15/11.3/ 4/ 9
	0.340	100	550 /387 /261 /384	41.0/39.8/39.5 /45.6	17/11.3/ 3/ 9
			39(21)/33(41)/52(36)	26(17)/22(22)/23(9)	
Zuni	0.163	150	474 /537 /2239 /2659	98 /32 /78 /82	12/340/337/349
	0.105	100	2761 /1088 /3619 /4684	125 /44 /96 /110	17/340/337/349
	0.180	50	6187 /3055 /6660 /10760	138 /74 /121 /168	27/340/338/349
		30	10950/5791 /9913 /18200	177 /103 /153 /216	33/340/340/349
			43(53)/105(16)/168(70)	55(51)/17(16)/18(19)	
Bravo (NRDL)	0.054	3000	5373 /-----/188 /----	177 /----/31 /----	72/---/ 90/---
	0.060	2000	13520/122 /413 /219	198 /24 /43 /30	69/ 94/ 90/ 89
	0.070	1000	23660/1074 /1798 /2613	237 /46 /73 /121	78/ 94/ 90/ 89
		500	40480/4113 /5444 /9056	298 /103 /112 /259	75/ 94/ 90/ 89
		100	76320/41590/27550/41620	559 /445 /268 /597	90/ 94/ 92/ 89

*Data taken from reference 1.

+Data taken from reference 7

‡A comparable Small Boy prediction by WSEG-10 is not available.

**Mean absolute percent errors: DNAF-1/DELFIC/WSEG-10. The values in parentheses are calculated without including the data for the highest activity level contours. See p. 53.

TABLE 4

OVERALL MEAN ABSOLUTE PERCENT ERRORS*

	Contour Area	Hotline Length
DNAF-1	66(58)	43(35)
DELFIC	62(42)	32(26)
WSEG-10	117(90)	51(45)

The Figure-of-Merit (FM) results do not show a consistent order of capabilities for the models. This is typical of past experience as well, and we have concluded that in its present form, FM does not provide a very useful measure of prediction capability. Details are given in Appendix C.

5.2 DISCUSSION OF THE TEST SHOT DATA AND PREDICTIONS

The three low yield shots were executed at the Nevada Test Site, and their fallout patterns were measured over land. For this reason, observed patterns for these shots, though not highly accurate, may be considered to be superior to the patterns of the high yield shots which were executed on Bikini Atoll in the South Pacific. Not only are the fallout fields of the high yield shots very large, which adds to measurement problems, but most of the fallout from these shots fell into water. Even so, most of the Koon pattern area was covered by an array of fallout collection stations, so this pattern is probably reasonably accurate. Zuni, on the other hand, is a special case. The fallout pattern used here is exclusively downwind of the atoll and was determined by an oceanographic survey method that was known to be inaccurate. The close-in pattern in the region of the atoll is available, but contains no closed contours so it could not be used here; thus the high-activity portion of the observed pattern for this shot is ignored

*Values in parentheses are calculated with data for the highest level contours excluded.

and this alone must account for a substantial portion of the disagreement between observation and prediction for this shot, particularly with regard to contour areas and contour overlap (Table 3). As already mentioned, we have no observed pattern for the Bravo shot. In addition, we have the following problem.

DNAF-1 and DELFIC predictions for the high yield shots are expected to be inferior to those for the low yield shots. This is because the high yield shots were detonated over coral soil, and in the cases of Zuni and Bravo, large but uncertain amounts of sea water were lifted by the clouds. The particle size distribution used for these predictions is typical of fallout produced from the siliceous soil found at the Nevada Test Site. We have not succeeded in developing a distribution appropriate for coral and coral-sea water mixtures.

DNAF-1 predictions were made using the H hour winds tabulated in reference 7. DELFIC predictions were made using all of the reference 7 wind profiles, from H hour onward in time. WSEG-10 calculations were done using $\vec{v}$ and S_Y values supplied by the DoD Command and Control Technical Center as determined by them from the H hour wind profiles; these data also are tabulated in reference 7 (Appendix A.3). For shots Small Boy and Bravo, the published wind data have been found to be not pertinent to transport of the nuclear clouds. For both of these cases, we have used reconstructed wind data: for Small Boy the reconstruction is described in Appendix B of reference 7, and for Bravo we have used the winds developed by Dean and Olmstead. Values of $\vec{v}$, ϕ and S_Y computed for the DNAF-1 predictions are given in Table 5.

TABLE 5

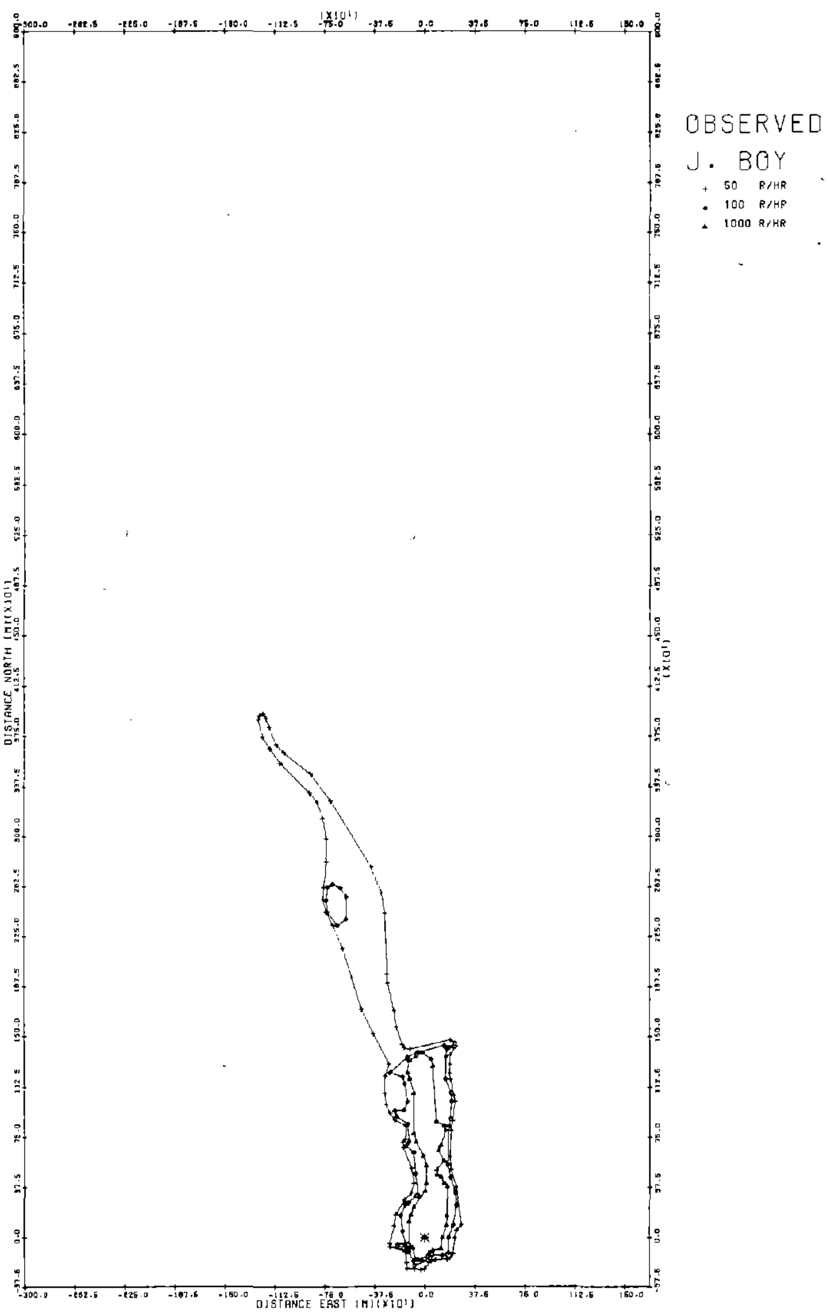
EFFECTIVE FALLOUT WINDS AND SHEAR PARAMETERS
COMPUTED FROM H HOUR WIND PROFILES FOR USE BY DNAF-1

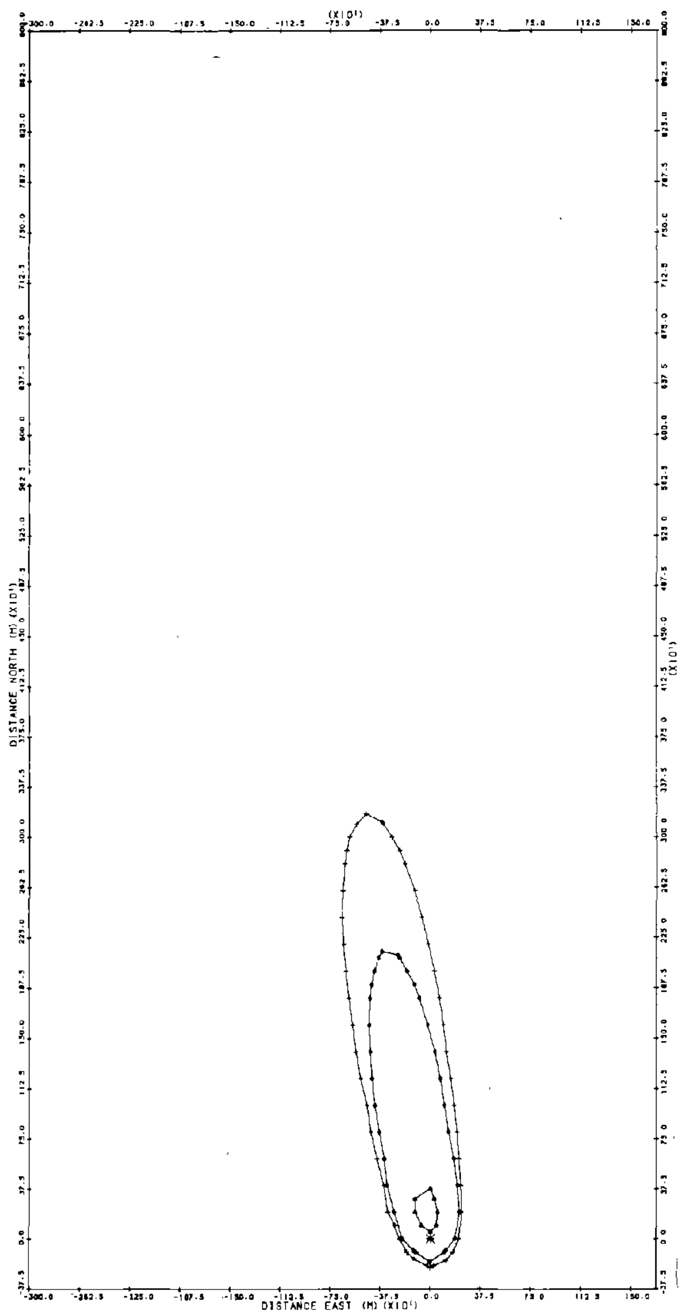
Test Shot	V ($m\ s^{-1}$)	ϕ (deg.)	S_Y (s^{-1})
Johnie Boy	6.0	- 8.6	0.00323
Jangle-S	13.1	14.6	0.00311
Small Boy	3.8	64.0	0.00066
Koon	6.2	11.3	0.00133
Zuni	4.9	-20.0	0.00225
Bravo	5.8	93.6	0.00044

5.3 OBSERVED AND PREDICTED FALLOUT PATTERNS

Contours are in units of Roentgens per hour for gamma radiation at a height of one meter above ground at H + 1 hour. All activity is assumed to be deposited at H + 1 hour. For all but the Zuni shot, for which fallout activity was measured by an oceanographic method, predicted activities are multiplied by a combined ground roughness-instrument response correction factor of 0.5. (See Appendix B.)

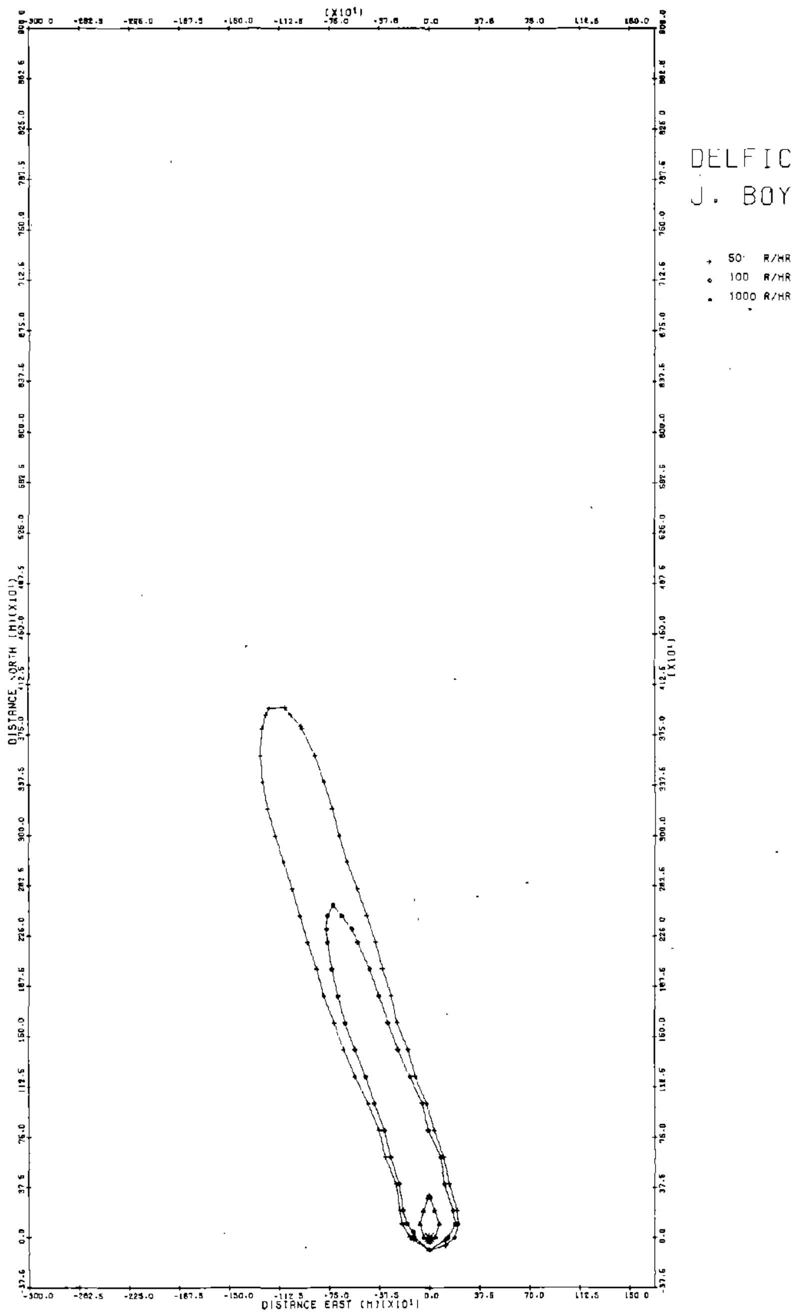
Observed and predicted patterns for each case are plotted to the same scale. North is up the pages and east is across the pages toward the right. Visual comparisons are best made by superimposing electrostatic copies of the plots.

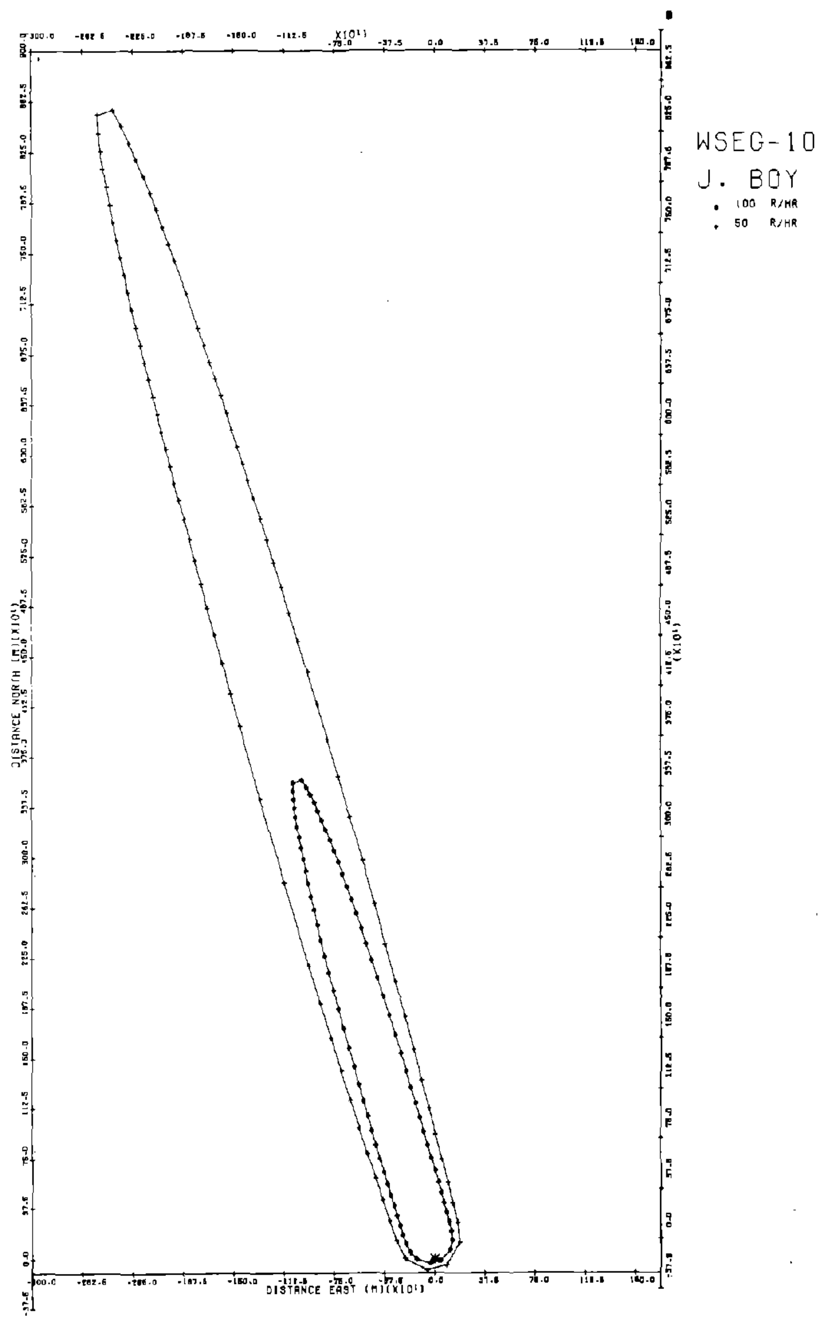

OBSERVED
J. BOY
+ 50 R/HR
• 100 R/HR
▲ 1000 R/HR
DISTANCE EAST (M)(X10¹)
DISTANCE NORTH (M)(X10¹)



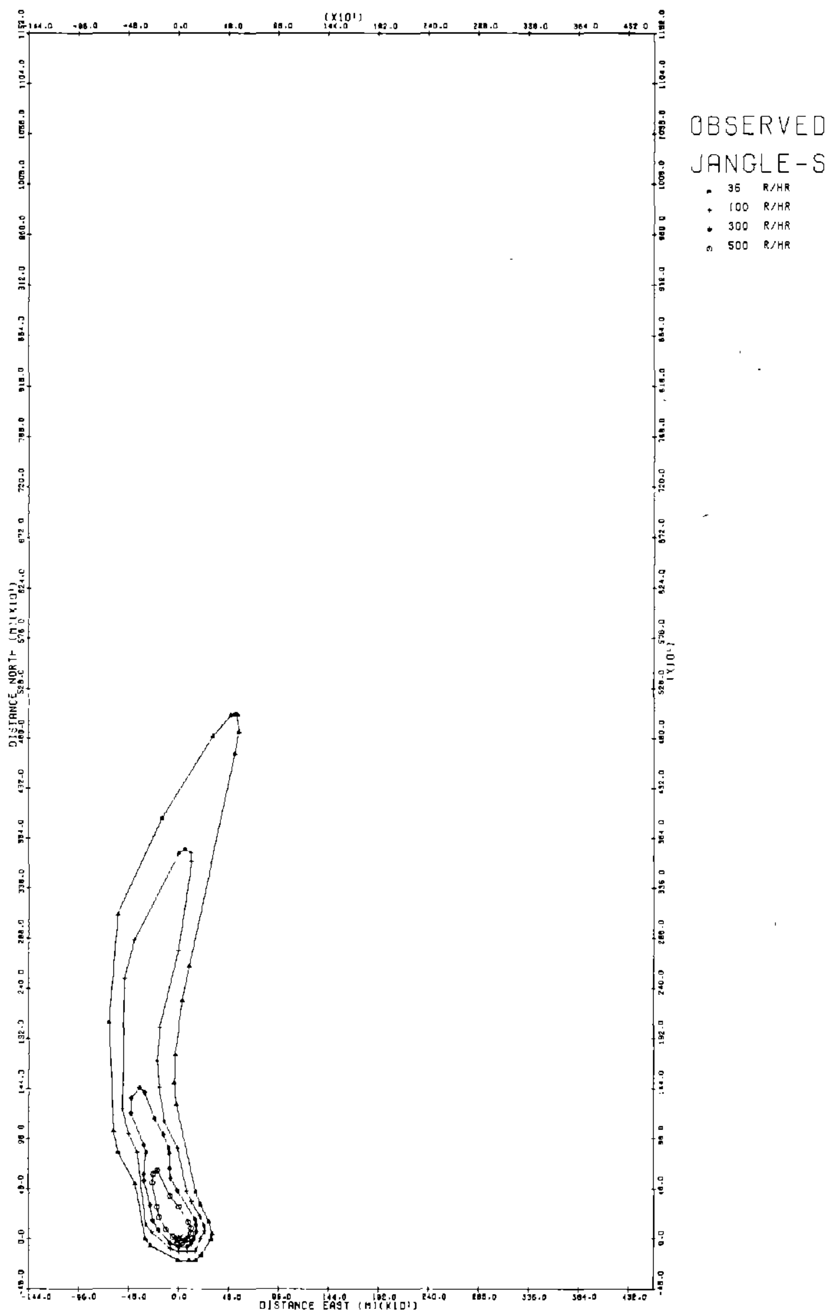
DNAF-1
J. BOY

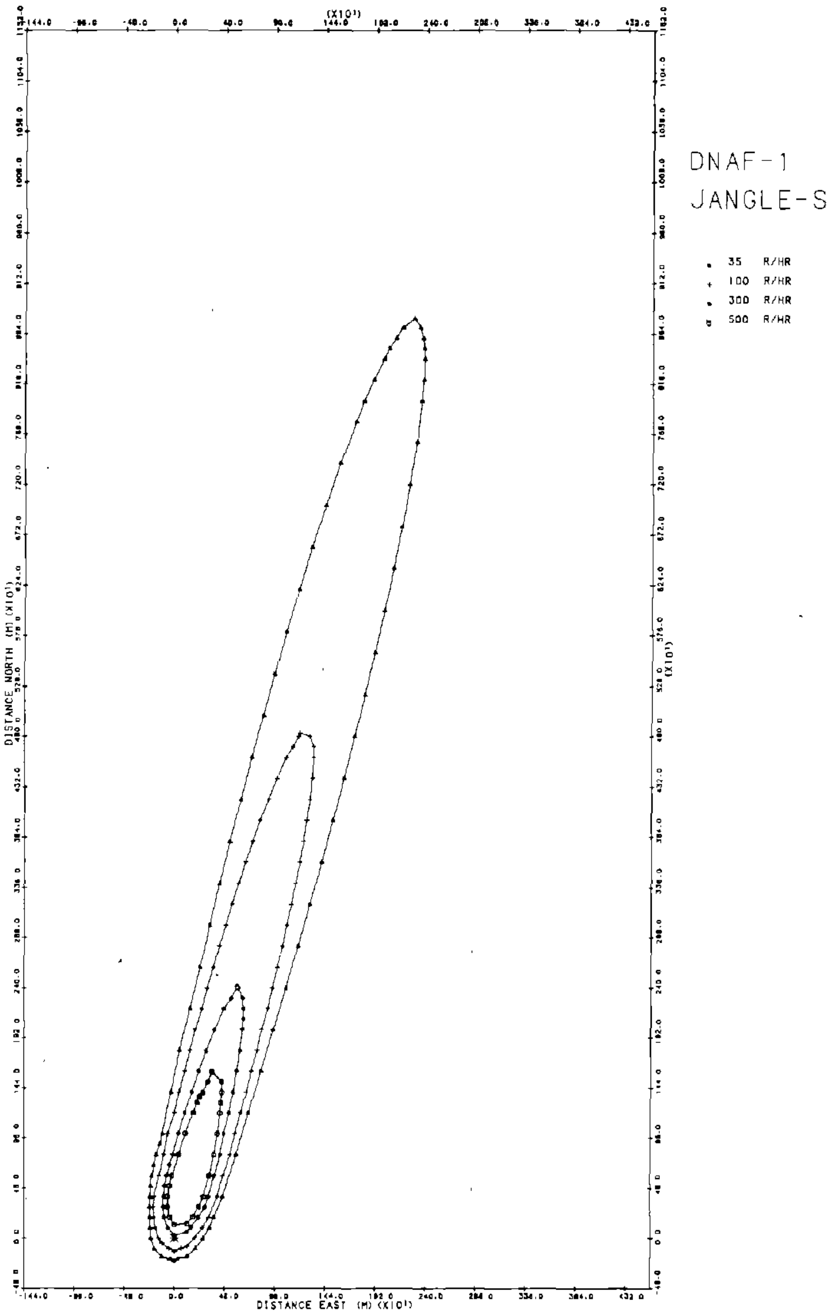
- 1000 R/HR
- 100 R/HR
- 50 R/HR

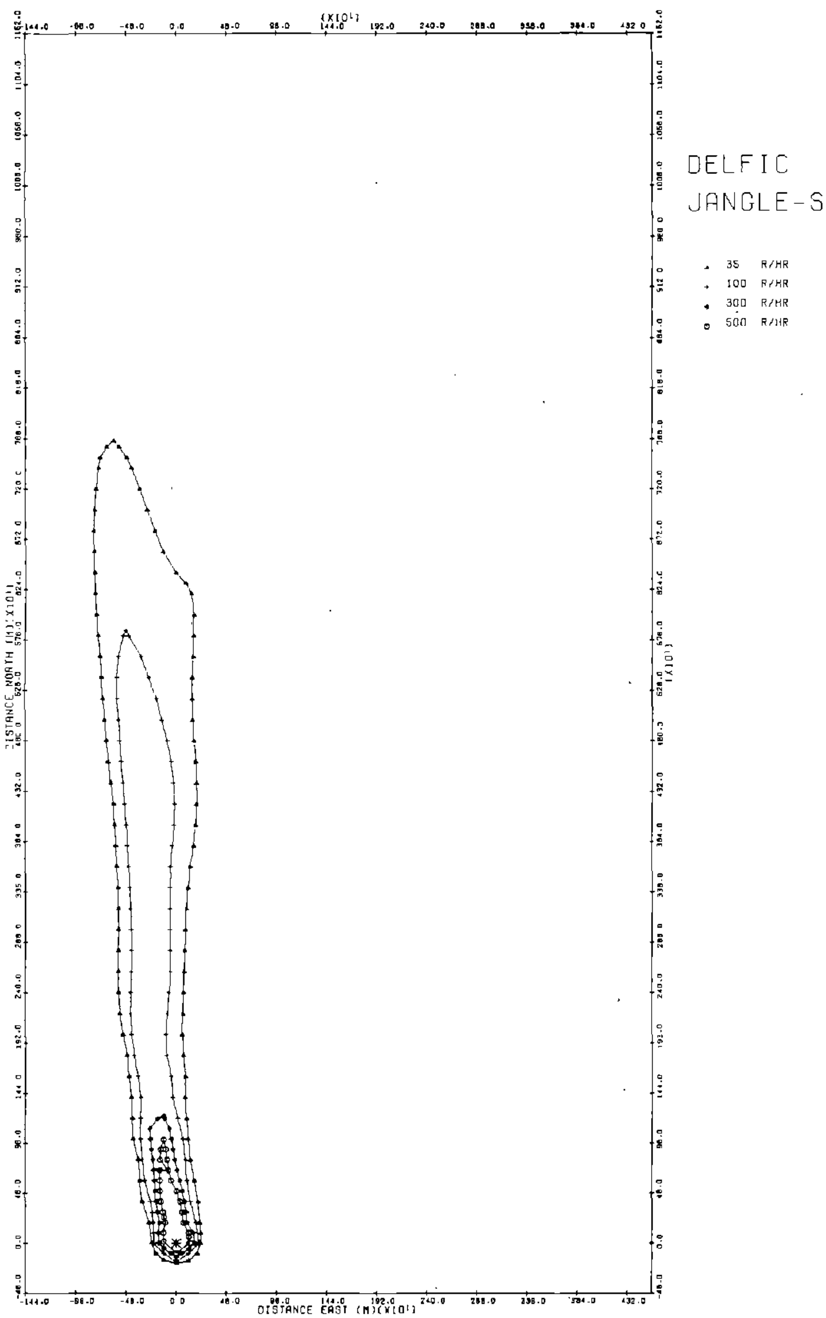

DELFIC
J. BOY
50 R/HR
100 R/HR
1000 R/HR
DISTANCE EAST (M)(X10¹)
DISTANCE NORTH (M)(X10¹)

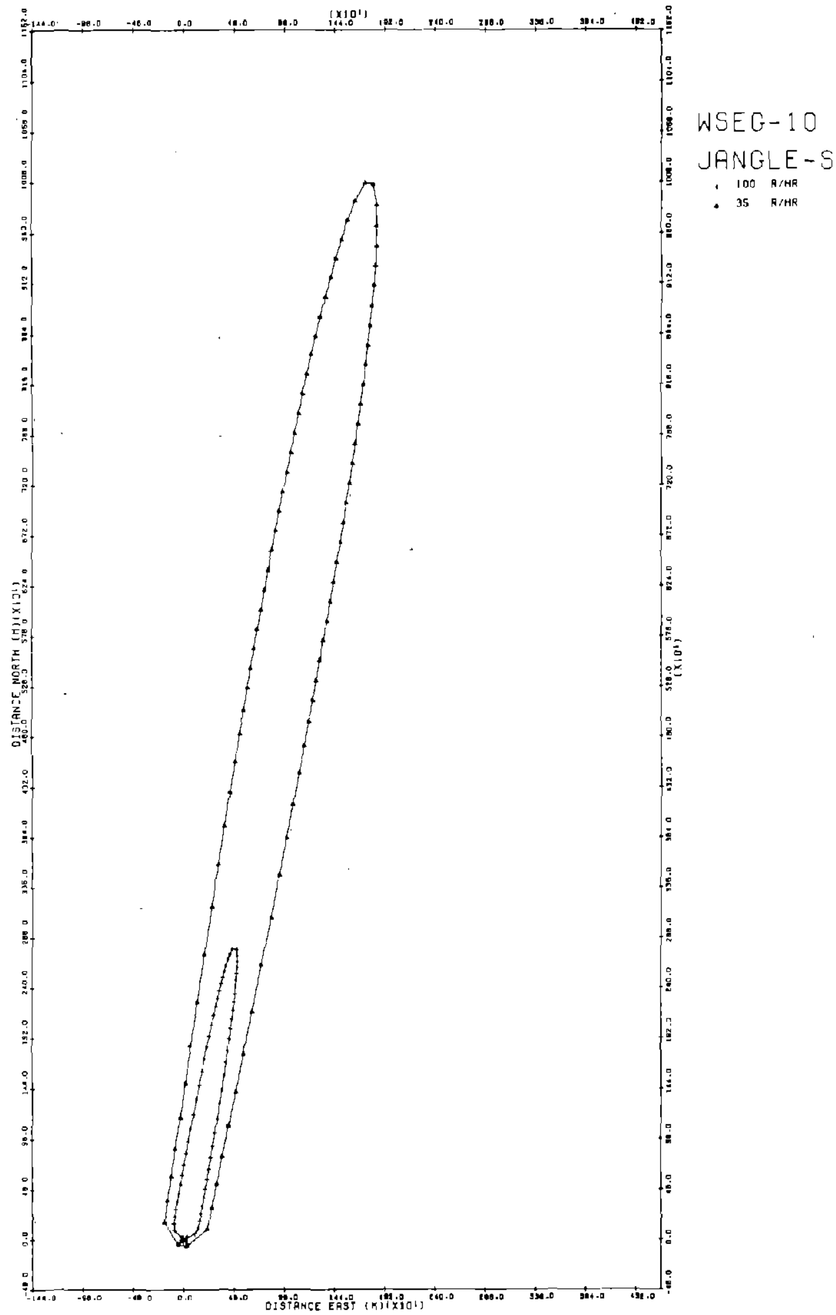


WSEG-10
J. BOY
100 R/HR
50 R/HR
DISTANCE EAST (M)(X10¹)
DISTANCE NORTH (M)(X10¹)

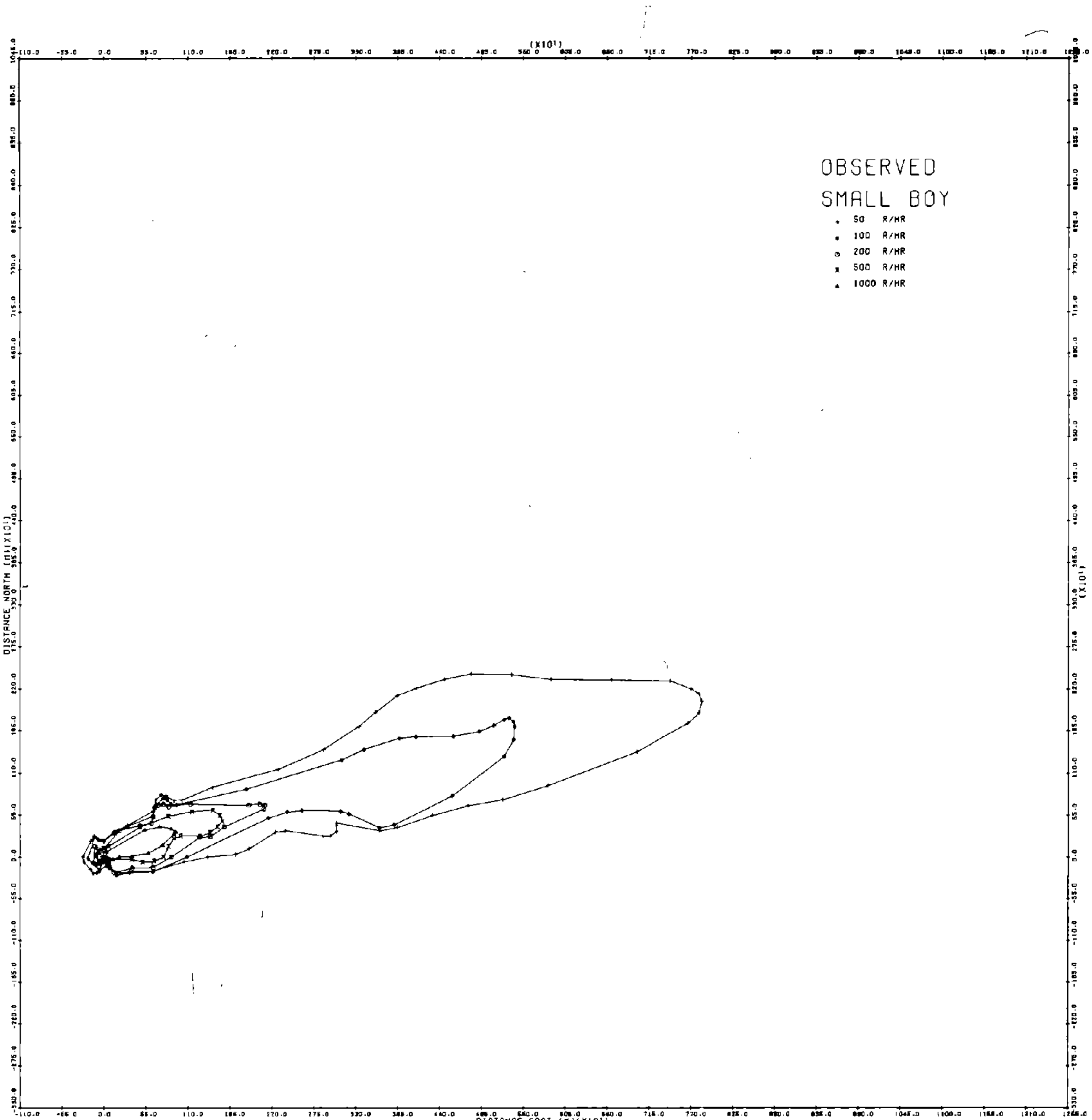

OBSERVED
JANGLE-S
35 R/HR
100 R/HR
300 R/HR
500 R/HR
DISTANCE EAST (M)(X10¹)
DISTANCE NORTH (M)(X10¹)
(X10¹)

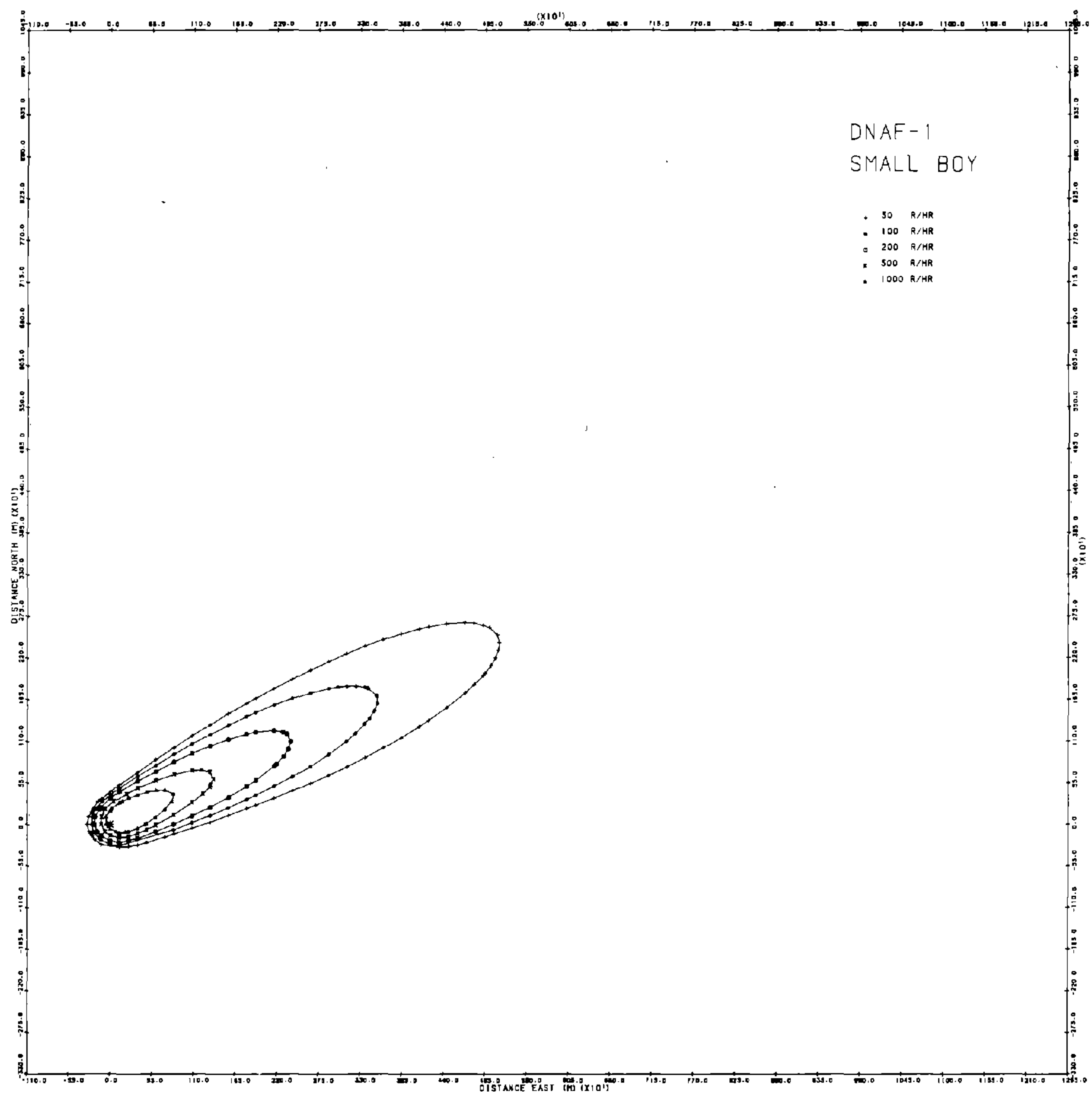

DNAF-1
JANGLE-S
35 R/HR
100 R/HR
300 R/HR
500 R/HR
DISTANCE EAST (M) (X10¹)
DISTANCE NORTH (M) (X10¹)

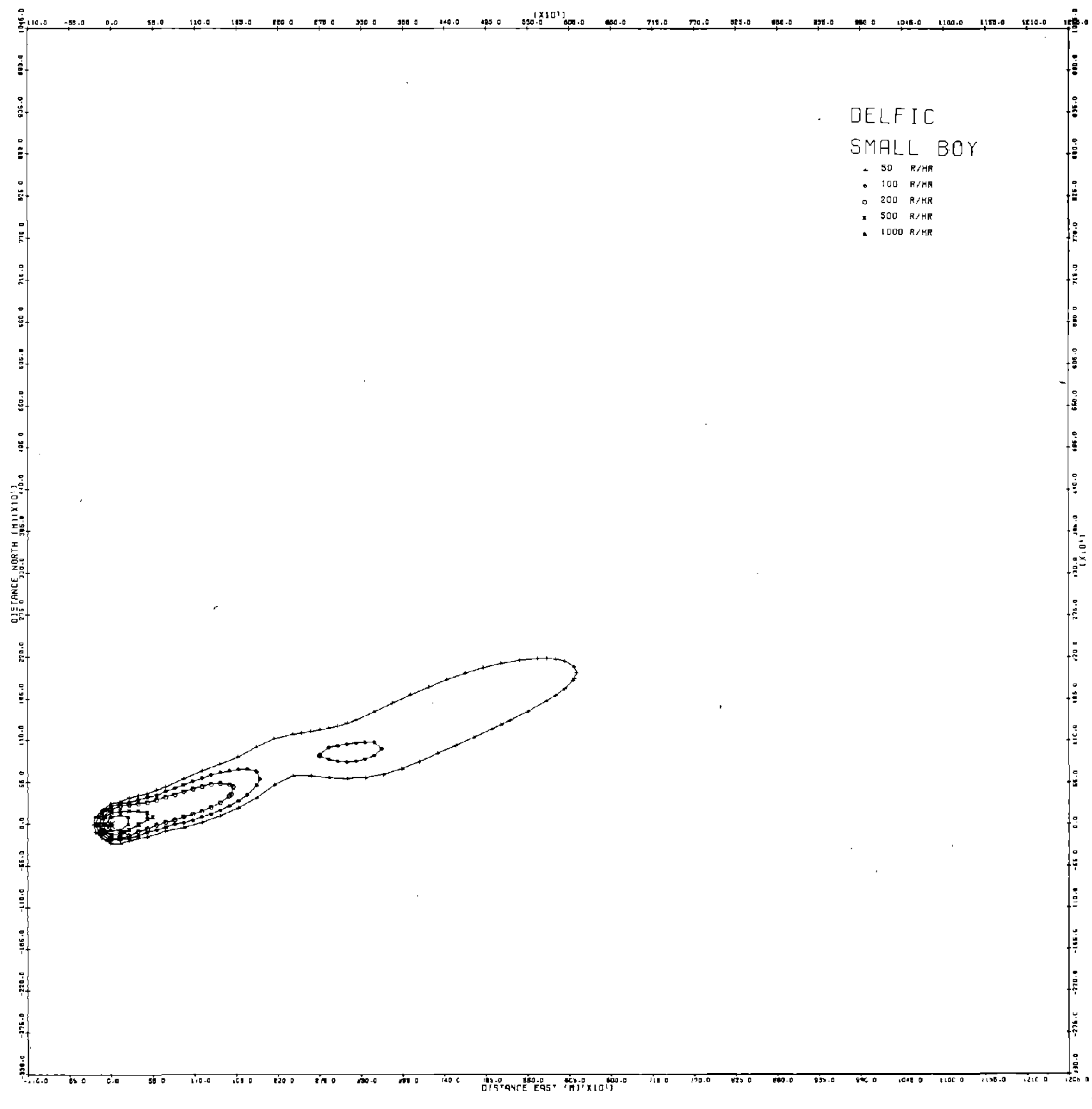

DELFIC
JANGLE-S
35 R/HR
100 R/HR
300 R/HR
500 R/HR
DISTANCE NORTH (M)(X10¹)
DISTANCE EAST (M)(X10¹)

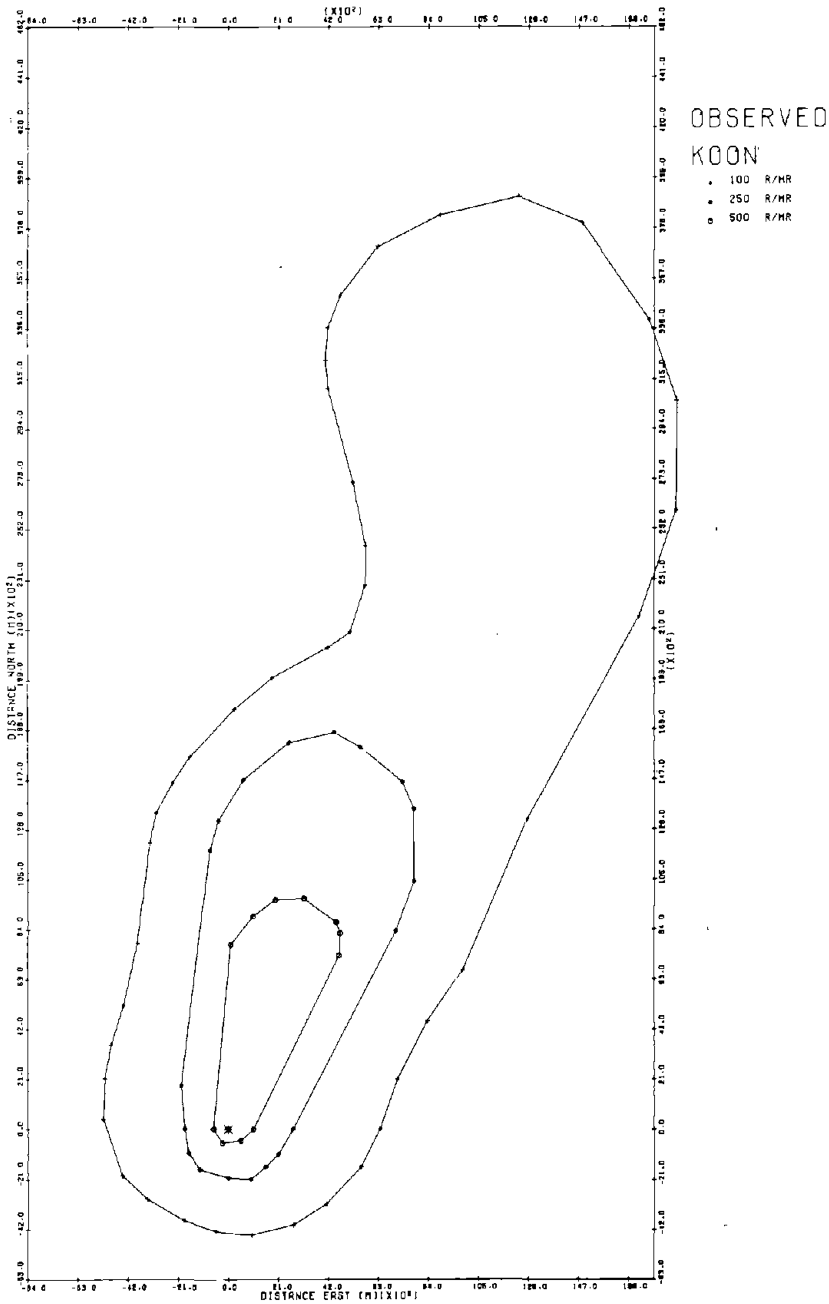


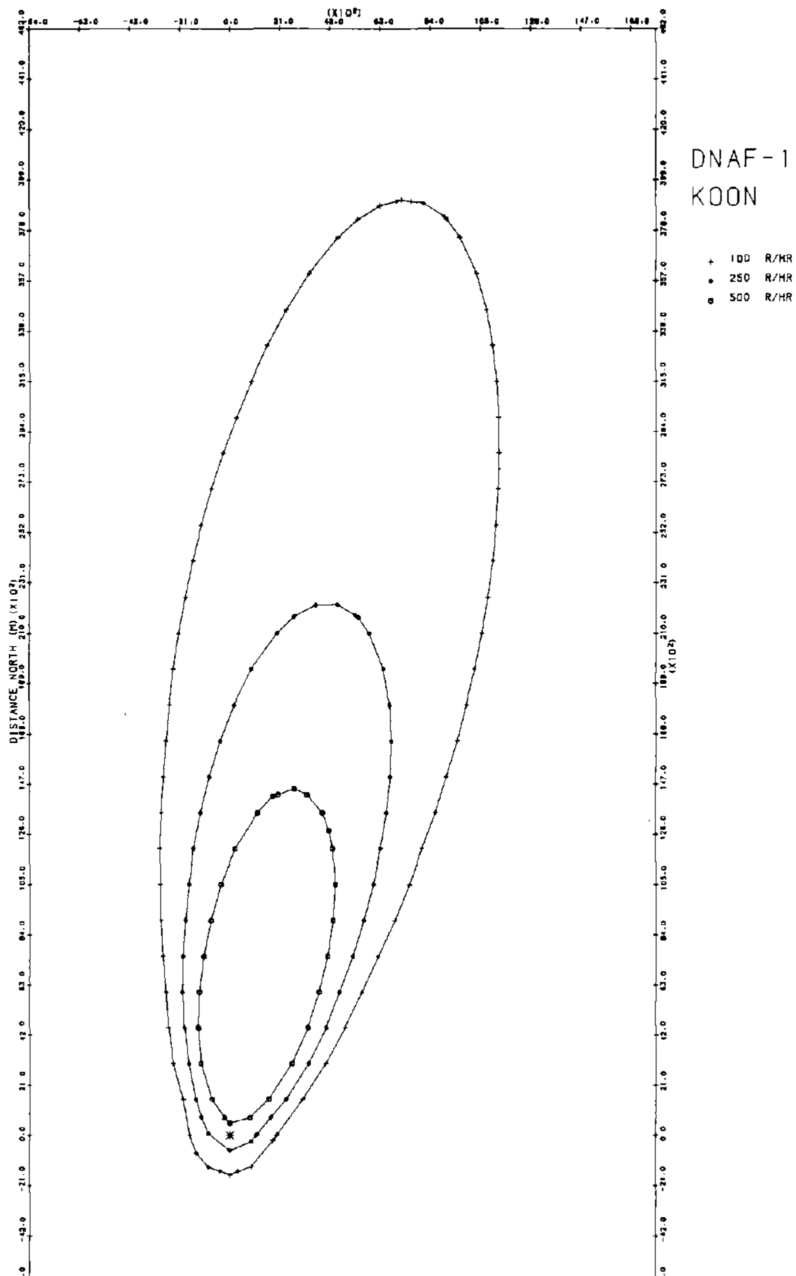
WSEG-10
JANGLE-S
100 R/HR
35 R/HR
DISTANCE EAST (M)(X10¹)
DISTANCE NORTH (M)(X10¹)

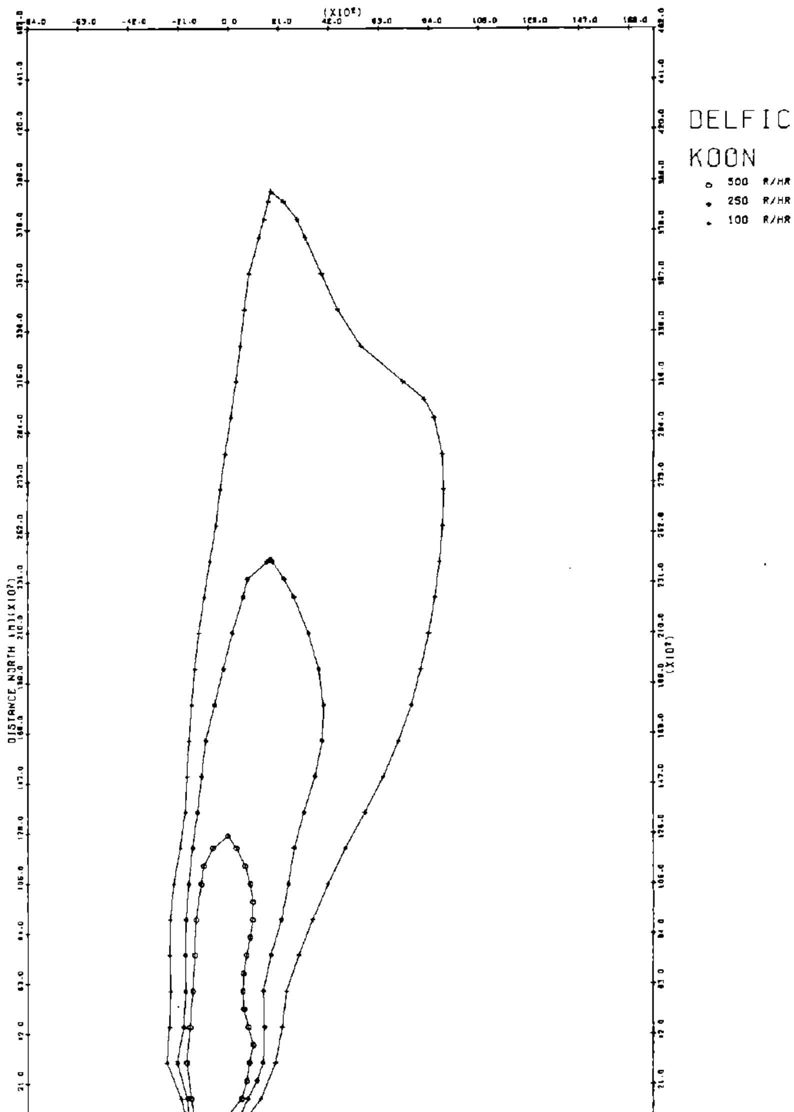

OBSERVED
SMALL BOY
50 R/HR
100 R/HR
200 R/HR
500 R/HR
1000 R/HR
DISTANCE EAST (MI)(X10¹)
DISTANCE NORTH (MI)(X10¹)

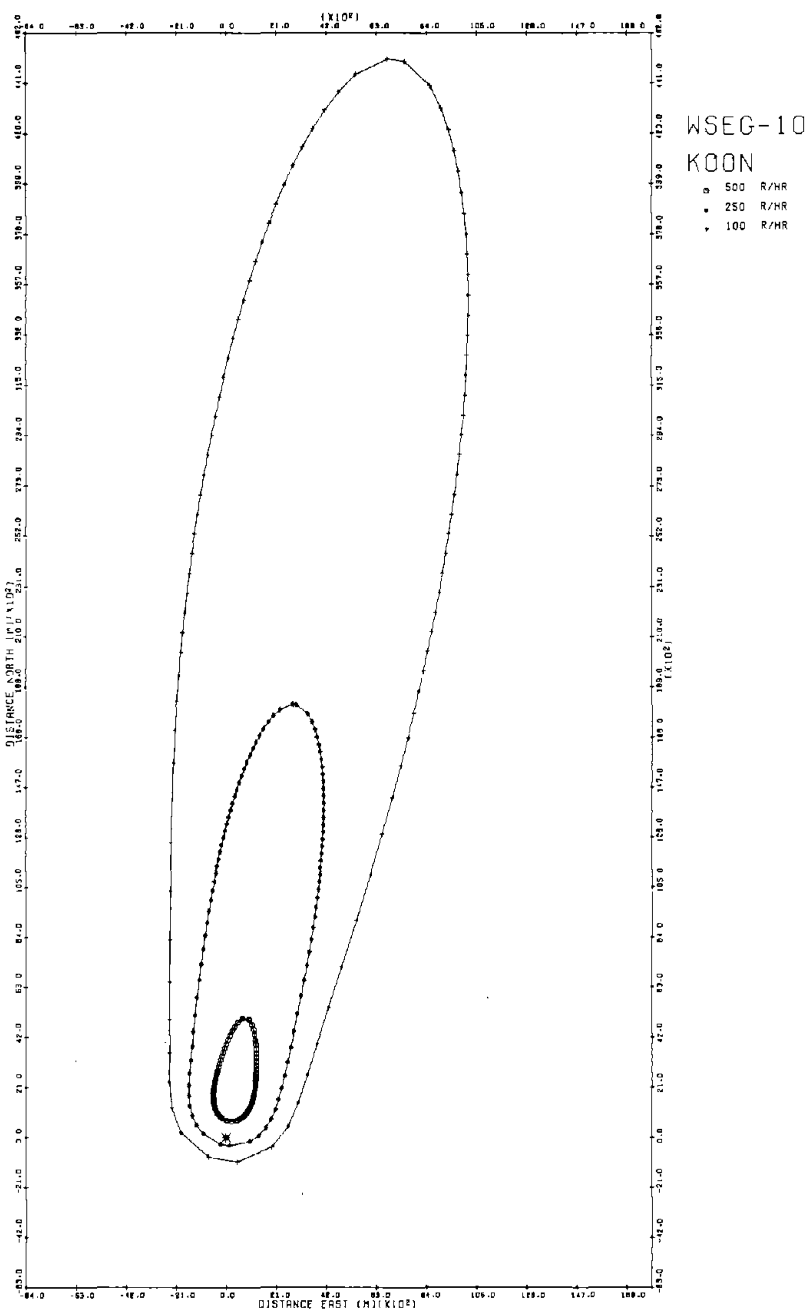

DNAF-1
SMALL BOY
50 R/HR
100 R/HR
200 R/HR
500 R/HR
1000 R/HR
DISTANCE NORTH (M) (X10¹)
DISTANCE EAST (M) (X10¹)

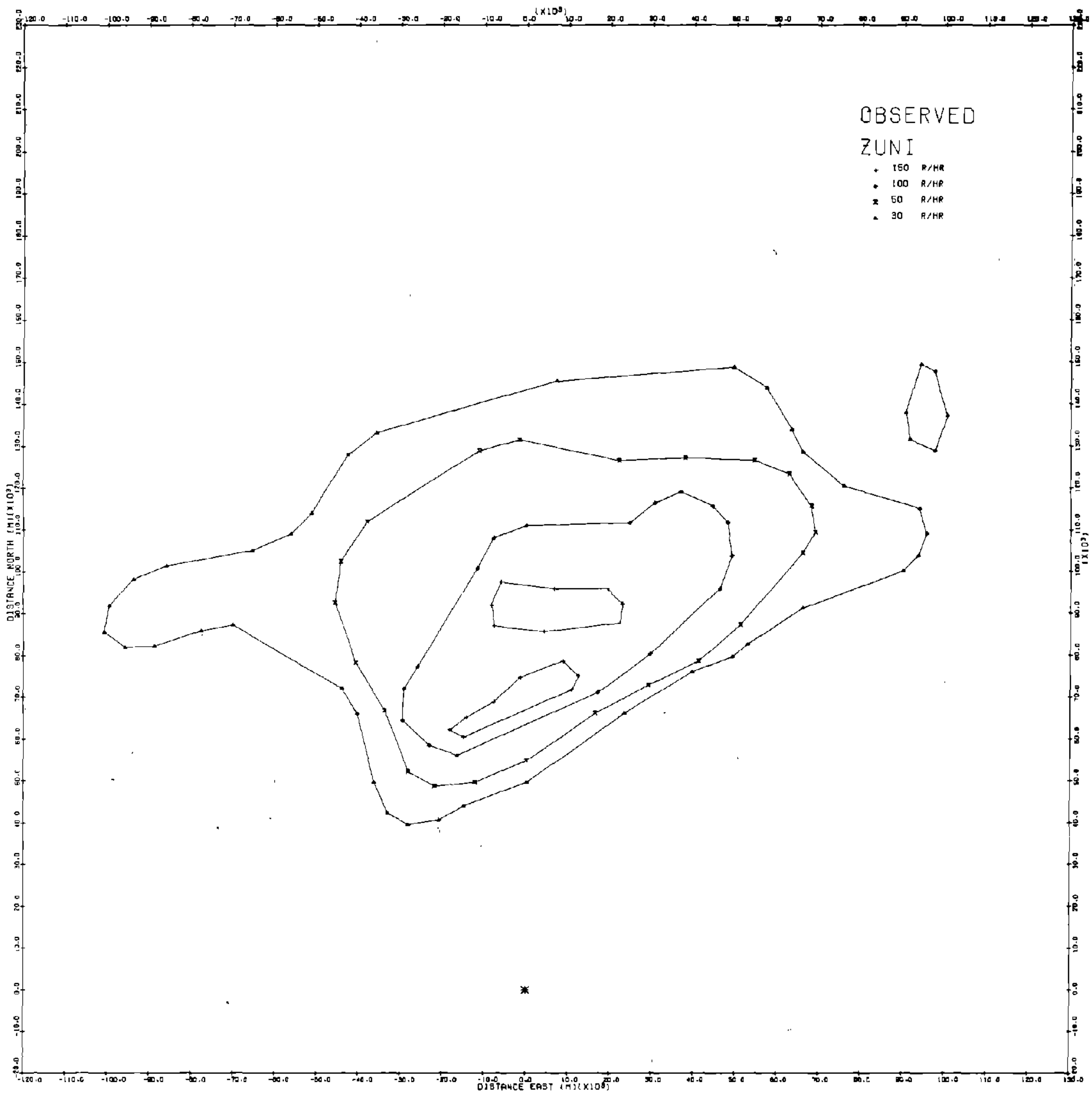

DELFIC
SMALL BOY
50 R/HR
100 R/HR
200 R/HR
500 R/HR
1000 R/HR
DISTANCE EAST (M)(X10¹)
DISTANCE NORTH (M)(X10¹)

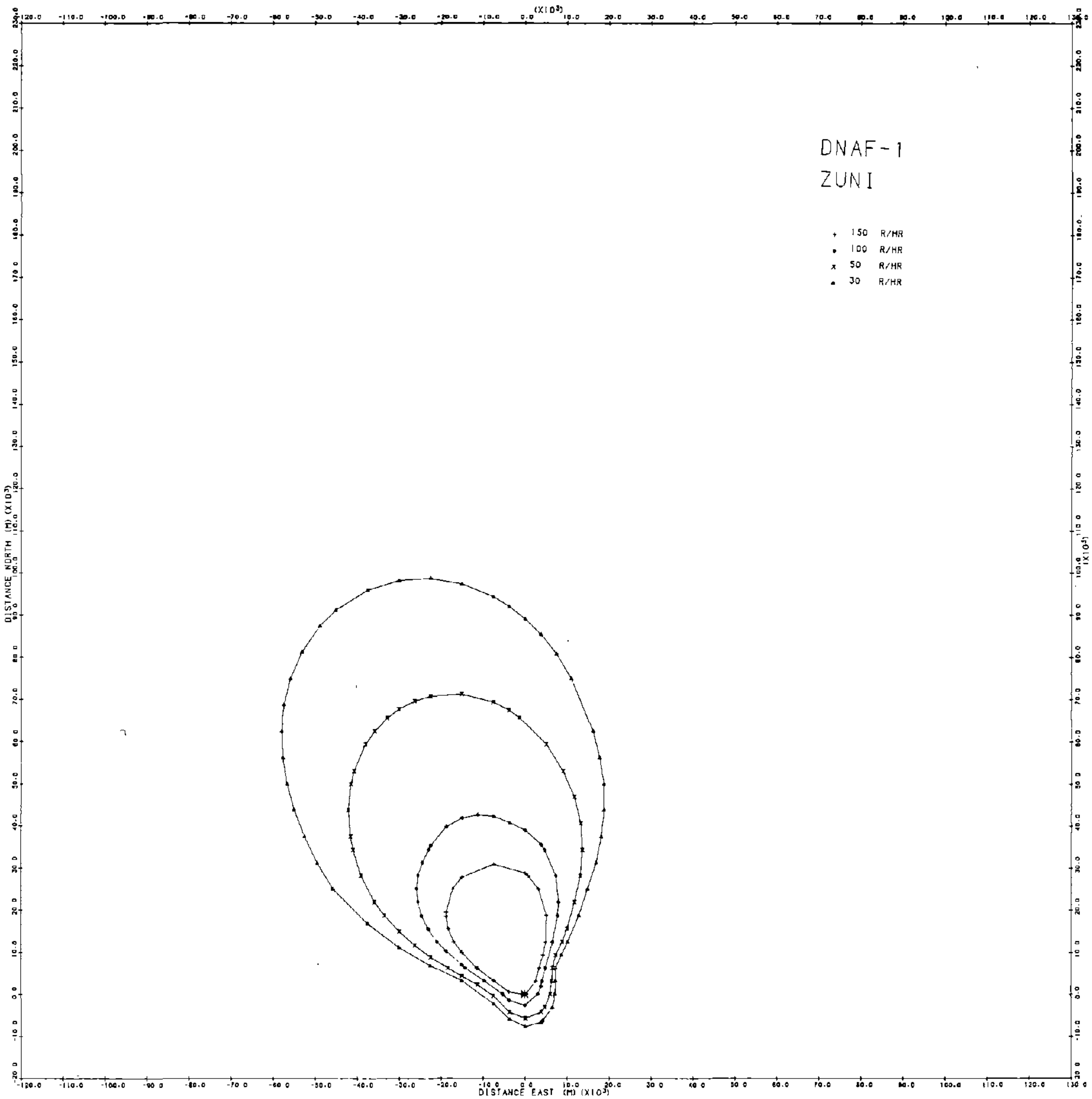

OBSERVED
KOON
100 R/HR
250 R/HR
500 R/HR

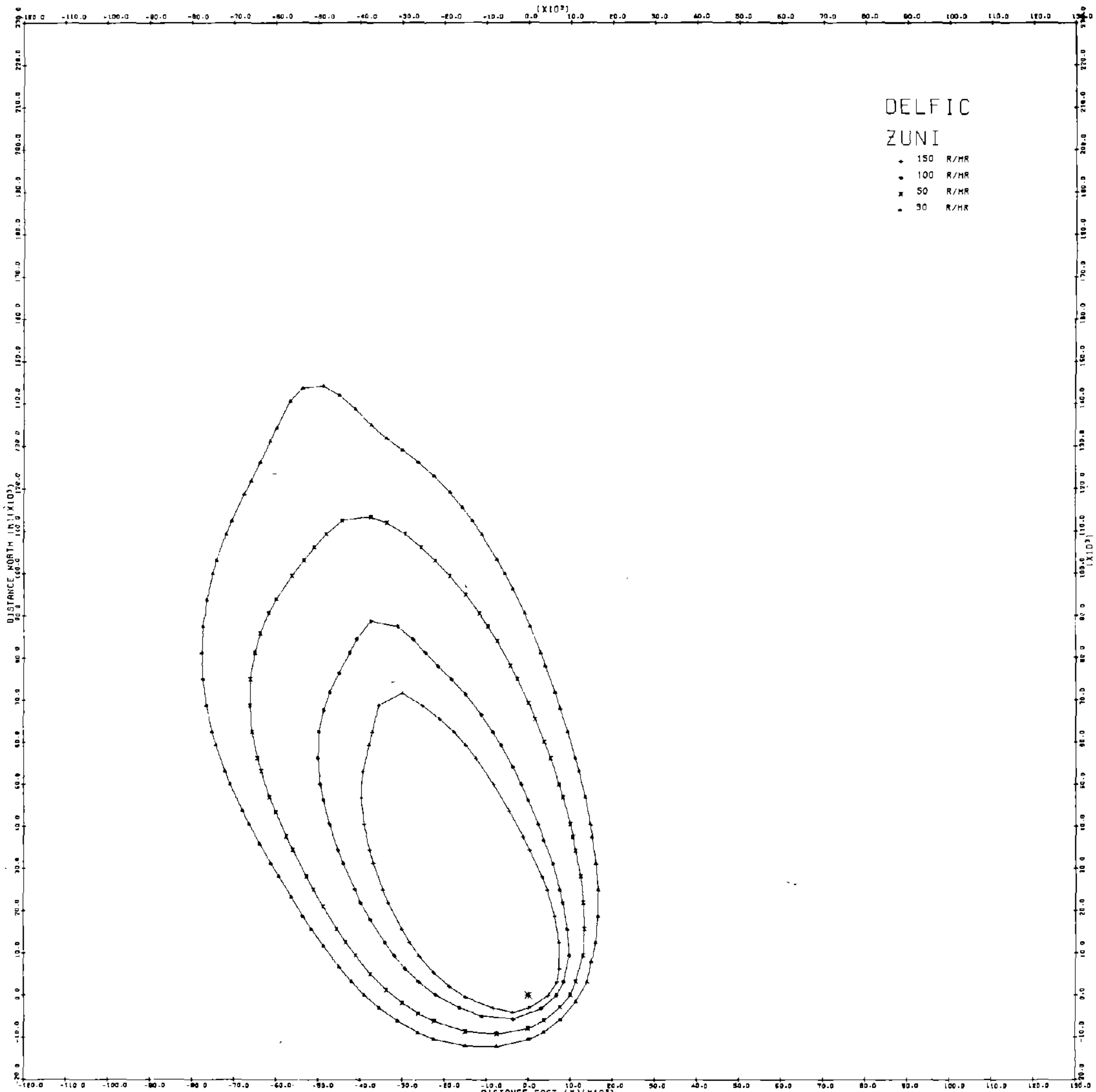

DNAF-1
KOON
+ 100 R/HR
• 250 R/HR
o 500 R/HR
DISTANCE EAST (M) (X10²)
DISTANCE NORTH (M) (X10²)

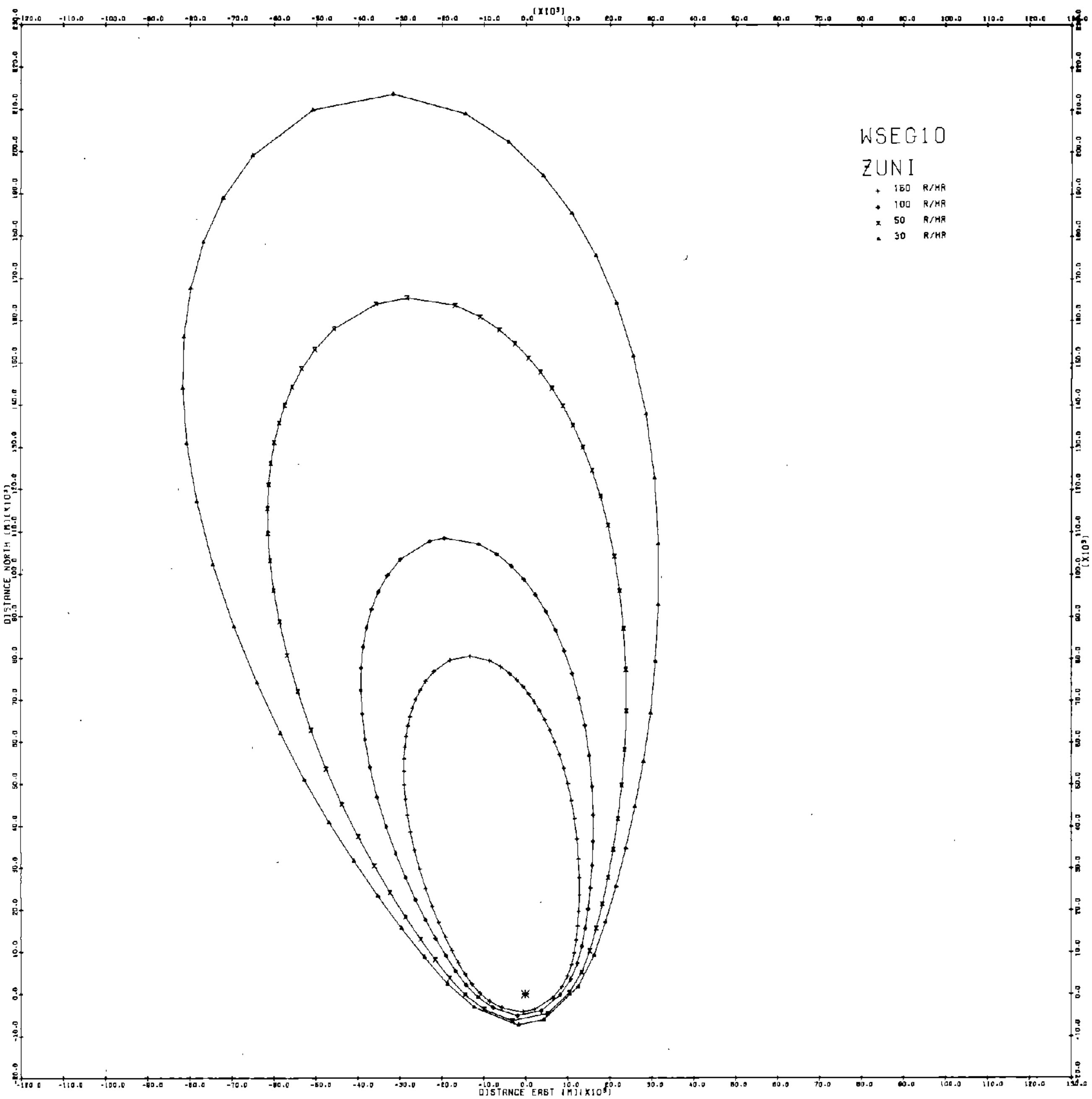

DELFIC
KOON
500 R/HR
250 R/HR
100 R/HR
DISTANCE EAST (M)(X10²)
DISTANCE NORTH (M)(X10²)

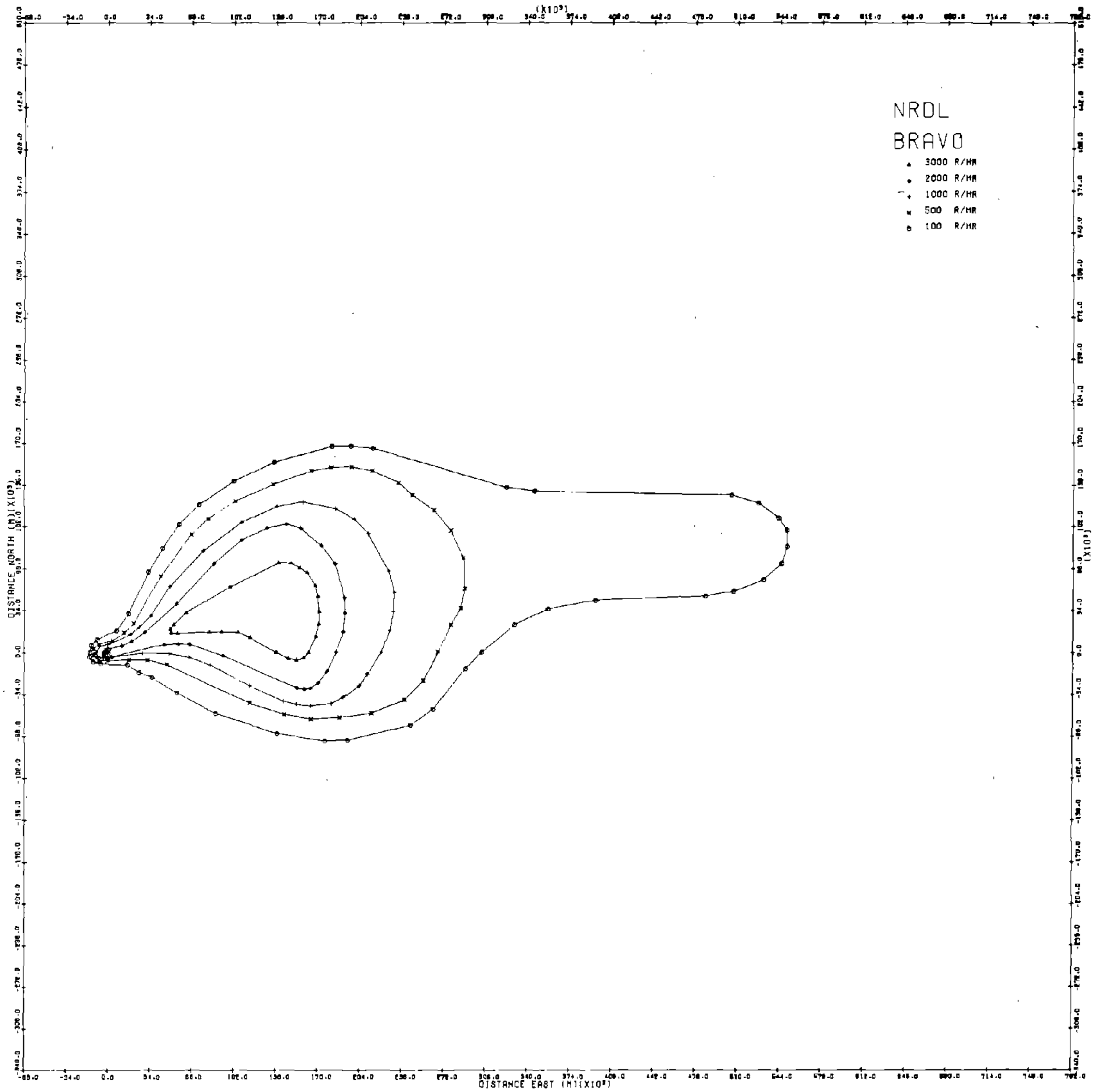

WSEG-10
KOON
500 R/HR
250 R/HR
100 R/HR
DISTANCE EAST (M)(X10²)
DISTANCE NORTH (M)(X10²)

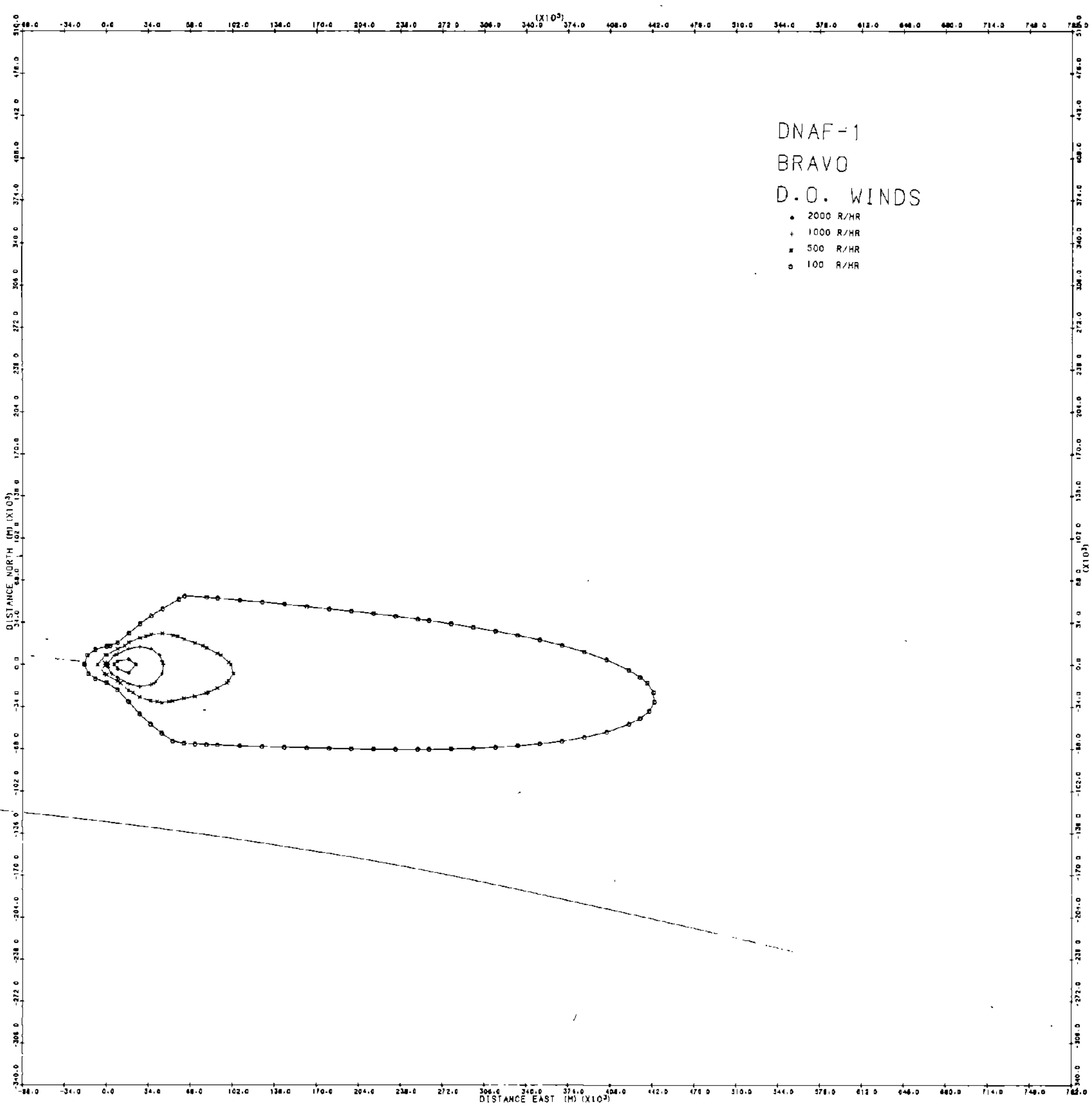

OBSERVED
ZUNI
150 R/HR
100 R/HR
50 R/HR
30 R/HR
DISTANCE NORTH (M)(X10³)
DISTANCE EAST (M)(X10³)

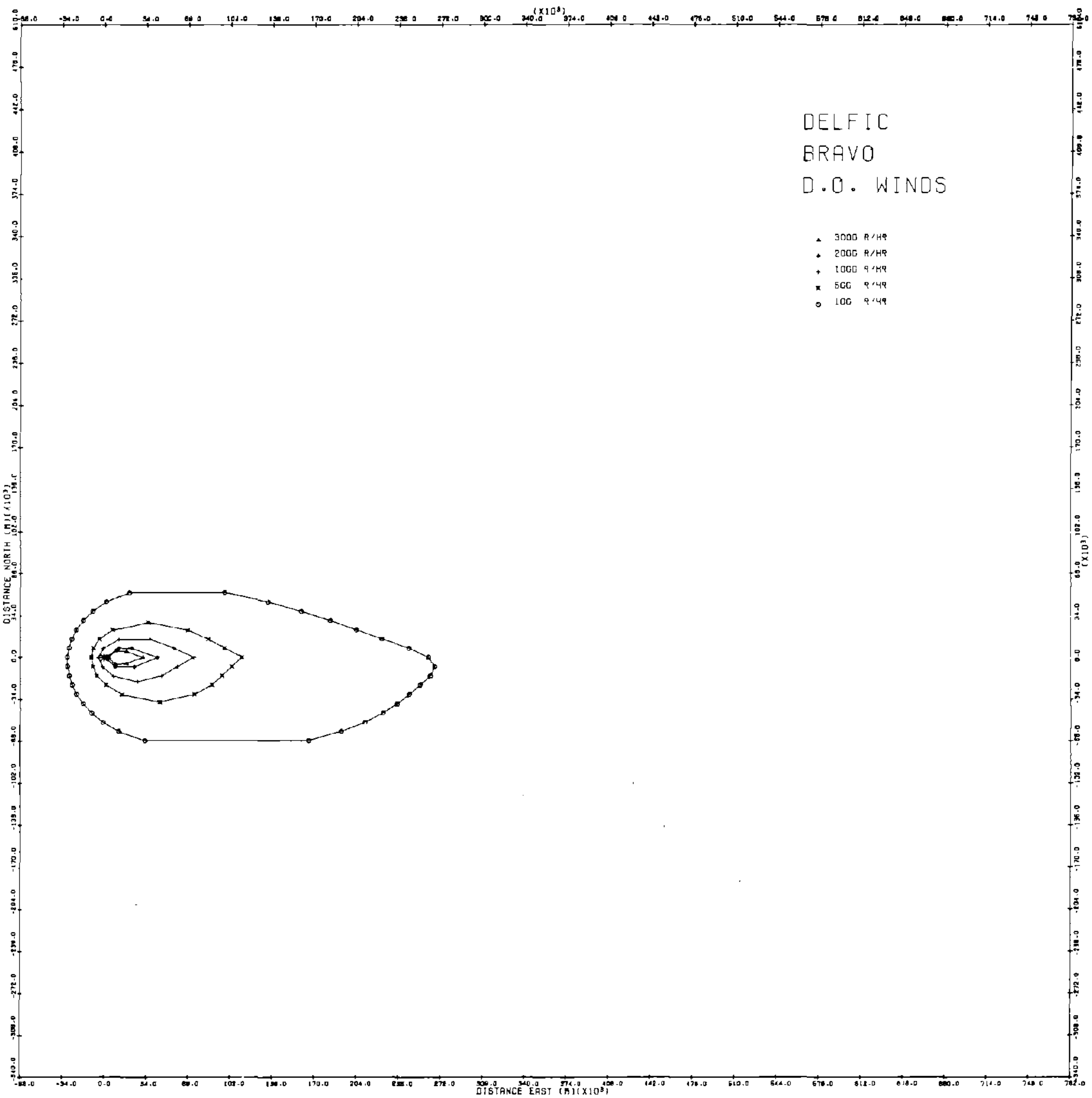

DNAF-1
ZUNI
+ 150 R/HR
• 100 R/HR
x 50 R/HR
▲ 30 R/HR
DISTANCE EAST (M) (X10³)
DISTANCE NORTH (M) (X10³)

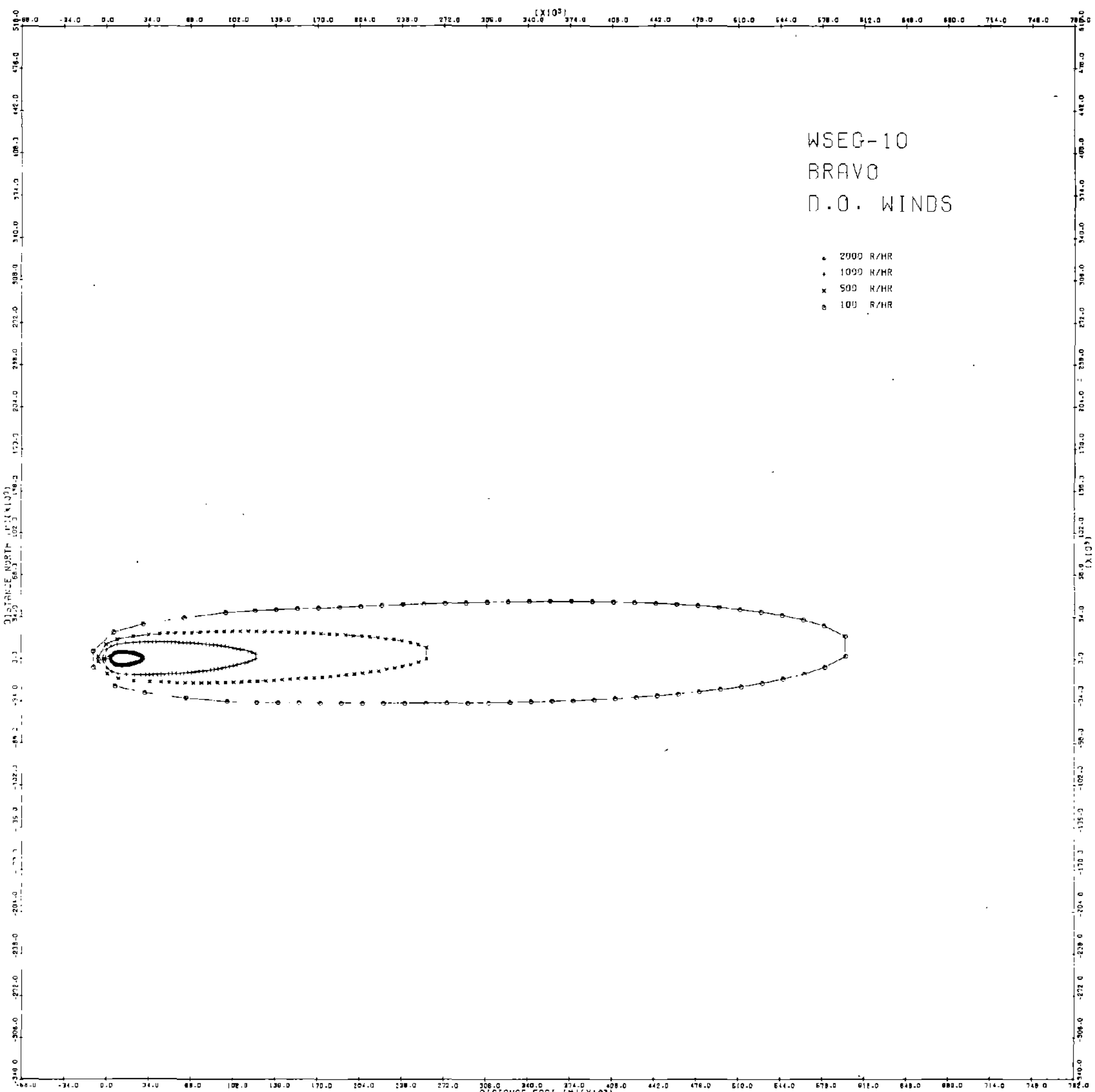

DELFIC
ZUNI
150 R/HR
100 R/HR
50 R/HR
30 R/HR
DISTANCE EAST (M)(X10³)
DISTANCE NORTH (M)(X10³)


WSEG10
ZUNI
150 R/HR
100 R/HR
50 R/HR
30 R/HR
DISTANCE NORTH (M)(X10³)
DISTANCE EAST (M)(X10³)


NRDL
BRAVO
3000 R/HR
2000 R/HR
1000 R/HR
500 R/HR
100 R/HR
DISTANCE NORTH (M)(X10³)
DISTANCE EAST (M)(X10³)


DNAF-1
BRAVO
D.O. WINDS
2000 R/HR
1000 R/HR
500 R/HR
100 R/HR
DISTANCE EAST (M) (X10³)
DISTANCE NORTH (M) (X10³)


DELFIC
BRAVO
D.O. WINDS
3000 R/HR
2000 R/HR
1000 R/HR
500 R/HR
100 R/HR
DISTANCE NORTH (M)(X10³)
DISTANCE EAST (M)(X10³)


WSEG-10
BRAVO
D.O. WINDS
2000 R/HR
1000 R/HR
500 R/HR
100 R/HR
DISTANCE EAST (MI)(X10³)
DISTANCE NORTH (MI)(X10³)

REFERENCES

1. H. G. Norment, "DELFIC: Department of Defense Fallout Prediction System. Volume I - Fundamentals," Atmospheric Science Associates, DNA 5159F-1 (31 December 1979). AD A088 367.

2. H. G. Norment, "DELFIC: Department of Defense Fallout Prediction System. Volume II - User's Manual," Atmospheric Science Associates, DNA 5159F-2 (31 December 1979). AD A088 512.

3. H. G. Norment, "SIMFIC: A Simple, Efficient Fallout Prediction Model," Atmospheric Science Associates, DNA 5193F (31 December 1979). AD A089 187/9.

4. G. E. Pugh and R. J. Galiano, "An Analytical Model for Close-In Operational-Type Studies," Weapons Systems Evaluation Group, WSEG RM No. 10 (15 October 1959). AD 261 752.

5. R. B. Mason, L. Bragg and J. Sherby, "Description of Mathematics for the Single Integrated Damage Analysis Capability (SIDAC)", Command and Control Technical Center, TM 15-80 (13 June 1980).

6. H. G. Norment, "Analysis and Comparison of Fallout Prediction Models," Atmospheric Science Associates, unpublished.

7. H. G. Norment, "Evaluation of Three Fallout Prediction Models: DELFIC, SEER and WSEG-10," Atmospheric Science Associates, DNA 5285F (16 June 1978).

8. U.S. Standard Atmosphere, 1976, NOAA, NASA, NOAA-S/T 76-1562 (October 1976).

9. L. F. Shampine and R. C. Allen, Numerical Computing: An Introduction (W. B. Saunders Co., 1973).

10. E. F. Wilsey and C. Crisco, "An Improved Method to Predict Nuclear Cloud Heights," Ballistics Research Laboratory, unpublished.

11. G. K. Batchelor, "Diffusion in a Field of Homogeneous Turbulence. I. Eulerian Analysis," Australian J. Sci. Res. 2A, 437 (1949).

12. A. C. Best, "Empirical Formulae for the Terminal Velocity of Water Drops Falling Through the Atmosphere," Quart. J. Roy. Meteor. Soc. 76, 302 (1950).

REFERENCES, continued

13. J. J. Walton, "Scale Dependent Diffusion," J. Appl. Meteor. 12, 547 (1973).

14. E. M. Wilkins, "Decay Rates for Turbulent Energy Throughout the Atmosphere," J. Atm. Sci. 20, 473 (1963).

15. H. G. Norment, "Validation and Refinement of the DELFIC Cloud Rise Module," Atmospheric Science Associates, DNA 4320F (15 January 1977). AD A047 372.

16. H. A. Blair, "The Constancy of Repair Rate and of Irreparability During Protracted Exposure to Ionizing Radiation," Ann. New York Acad. Sci. 114, 150 (1964).

17. H. O. Davidson, Biological Effects of Whole-Body Gamma Radiation on Human Beings (Johns Hopkins University Press, 1957).

18. S. Glasstone and P. J. Dolan, The Effects of Nuclear Weapons, 3rd Edition (Department of Defense and Department of Energy, 1977). Sec. 9.146 ff.

19. R. L. Stetson, et. al., "Operation Castle, Proj. 2.5a. Distribution and Intensity of Fallout," U. S. Naval Radiological Defense Laboratory, unpublished.

20. R. H. Rowland and J. H. Thompson, "A Method for Comparing Fallout Patterns," DASIAC, G. E. - Tempo, DNA 2919F (April 1972).

APPENDIX B

GROUND ROUGHNESS AND INSTRUMENT RESPONSE CORRECTION FACTORS

To compare predicted H + 1 hour gamma exposure rates in a fallout field with values measured over land by radiation survey meters, it is necessary to make certain adjustments to either the observed or predicted values. Conventional practice is to adjust the predictions.

Predicted exposure rates are based on laboratory measurements of fission product yields and on factors called exposure rate multipliers that convert the fission yields for individual nuclides to exposure rates at one meter height above an infinite plane on which the fission products are assumed to be uniformly distributed. One correction, the ground roughness factor, is required to account for absorption of radiation by small irregularities, or roughness elements, in an actual ground surface. The other correction is necessary to account for variation of response of survey meters to radiation over the spectrum of wave lengths encountered. Ground roughness factors for Nevada Test Site terrains are estimated to be in the range of 0.70 to 0.75, and an instrument response factor of about 0.75 is appropriate for commonly used survey meters. The product of these two factors is approximately 0.5, and this factor is applied to dose rates throughout all of the predicted test shot patterns except for Zuni as noted in section 5.3.